

Tutorial 2

Electric Charge



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Lecture Outline

- **Chapter 21**, D Halliday, R Resnick, and J Walker, “Fundamentals of Physics” 9th Edition, Wiley (2005).
- Electric Charge
 - Conductor and Insulators
 - Coulomb’s Law
 - Quantization of Charge
 - Charge Conservation

Lecture 02 – Review

- In Lecture 2 we introduced the properties of electric charges.
- Charge is not a substance rather it is a property of the particles.
- Electric charge has two different signs, positive or negative.
- A charged particle will encounter a force when it is placed near another charged particle.
- The charges repel each other if they have the same sign and attract each other when they have opposite signs.
- A conductor consists of mobile electrons that can move freely within the conductor, we call the mobile electrons conduction or free electrons.
- Insulators also have electrons, however these electrons are bounded to the atom and cannot move freely.



Lecture 02 – Review

- The force between two charged particles is called the electrostatic force, it is governed by the Coulomb's law.
- The magnitude of the force is proportional to the product of the charges and inversely proportional to the square of the displacement between the charges.

$$\vec{F} = k \frac{q_1 q_2}{r^2} \hat{r} \quad (\text{Coulomb's law}),$$

$$k = \frac{1}{4\pi\epsilon_0} = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2.$$

- The constant k is called the *electrostatic constant* and the quantity ϵ is called the *permittivity*.
- The quantity ϵ is the property of the medium between the two charged particles and ϵ_0 is the *vacuum permittivity*.
- We also defined current as the rate at which charge moves past a point, a surface, or a region.

Lecture 02 – Review

- The total force encountered by a charged particle when it is placed near a group of charged particles is given by the vector sum of the particle with each individual particles.
- When two conducting objects are connected by a conducting wire, the charges on the objects will be shared between them. As a result, the two objects will have the same amount of charges.
- A ground is a huge conductor and can be used to neutralize a charged object when connecting it with a wire.
- Charge is quantized $e=1.602 \times 10^{-19} \text{ C}$
- Conservation of charge means the total electric charge of an isolated system is constant and cannot be changed.

Practice Questions: Electric Charges

Chapter 21

Questions: 2,5,9,*2,**9,**16,*25

Q2

Figure 21-13 shows three pairs of identical spheres that are to be touched together and then separated. The initial charges on them are indicated. Rank the pair according to (a) the magnitude of the charge transferred during touching and (b) the charge left on the positively charged sphere, greatest first.

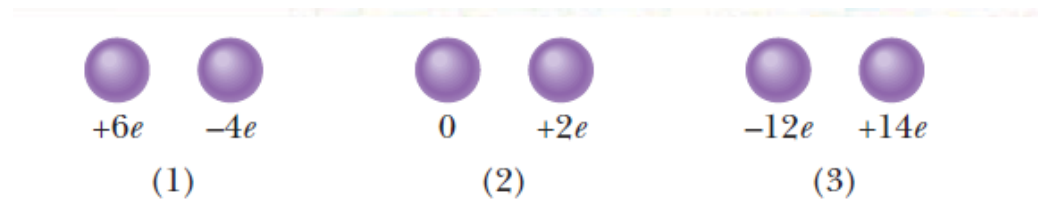


Fig. 21-13 Question 2.

	Before			After	
	QL	QR	Total	QL	QR
1	$+6e$	$-4e$	$+2e$	$+e$	$+e$
2	0	$+2e$	$+2e$	$+e$	$+e$
3	$-12e$	$+14e$	$+2e$	$+e$	$+e$

Q5

In Fig. 21-16, a central particle of charge $-q$ is surrounded by two circular rings of charged particles. What are the magnitude and direction of the net electrostatic force on the central particle due to the other particles?

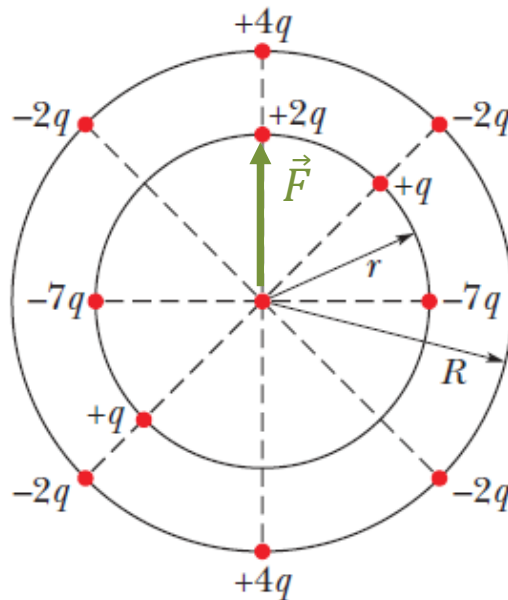
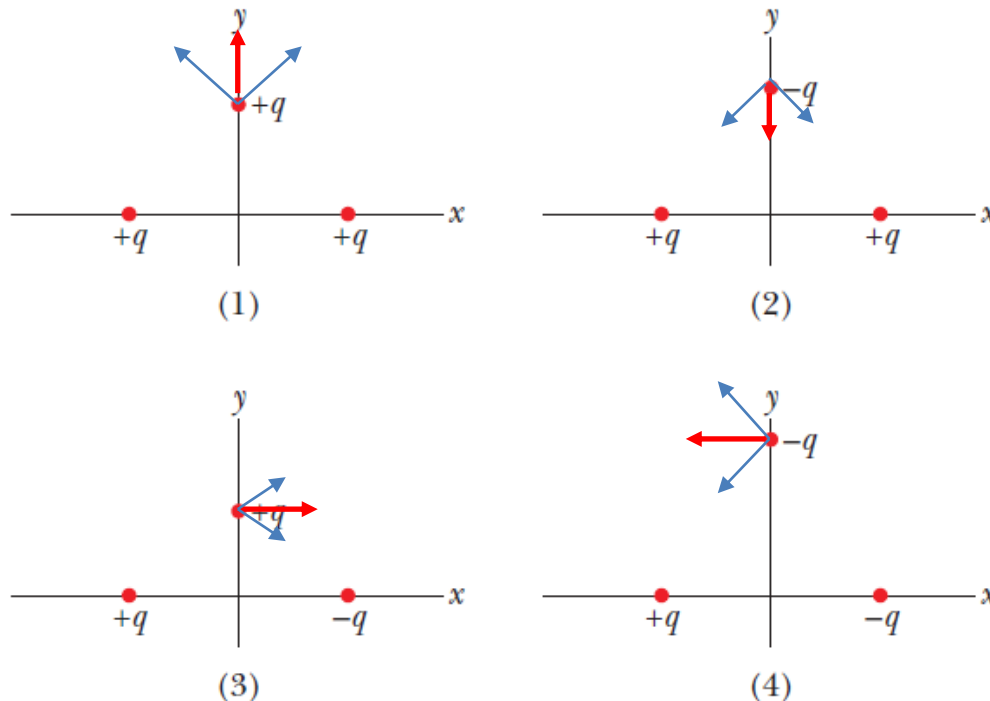


Fig. 21-16 Question 5.

$$F = k \frac{2q^2}{r^2}$$

Q9

Figure 21-19 shows four situations in which particles of charge $+q$ or $-q$ are fixed in place. In each situation, the particles on the x axis are equidistant from the y axis. First, consider the middle particle in situation 1; the middle particle experiences an electrostatic force from each of the other two particles. (a) are the magnitudes F of those forces the same or different? (b) Is the magnitude of the net force on the middle particle equal to, greater than, or less than $2F$? (c) Do the x components add or cancel? (d) Do their y components add or cancel? (e) Is the direction of the net force on the middle particle that of the canceling components or the adding components? (f) What is the direction of that net force? Now consider the remaining situations: What is the direction of the net force on the middle particle in (g) situation 2, (h) situation 3, and (i) situation 4? (in each situations, consider the symmetry of the charge distribution and determine the canceling components and the adding components.)



Q*2

Identical isolated conducting spheres 1 and 2 have equal charges and are separated by a distance that is large compared with their diameters (Fig. 21-21a). The electrostatic force acting on sphere 2 due to sphere 1 is $\vec{F}$. Suppose now that a third identical sphere 3, having an insulating handle and initially neutral, is touched first to sphere 1 (Fig. 21-21b), then to sphere 2 (Fig. 21-21c), and finally removed (Fig. 21-21d). The electrostatic force that now acts on sphere 2 has magnitude F' . What is the ratio F'/F

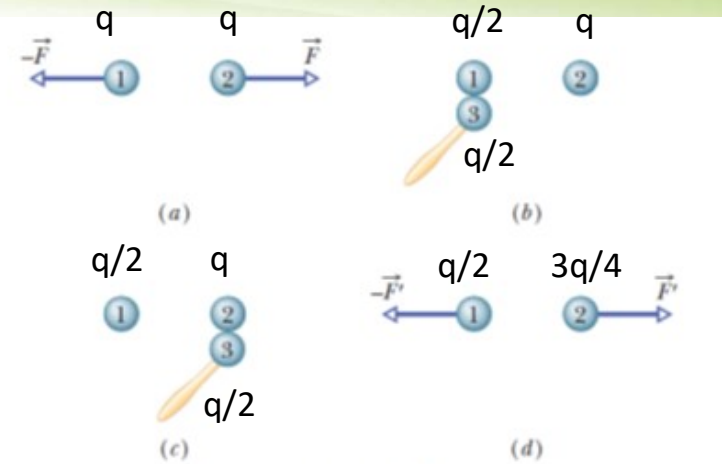
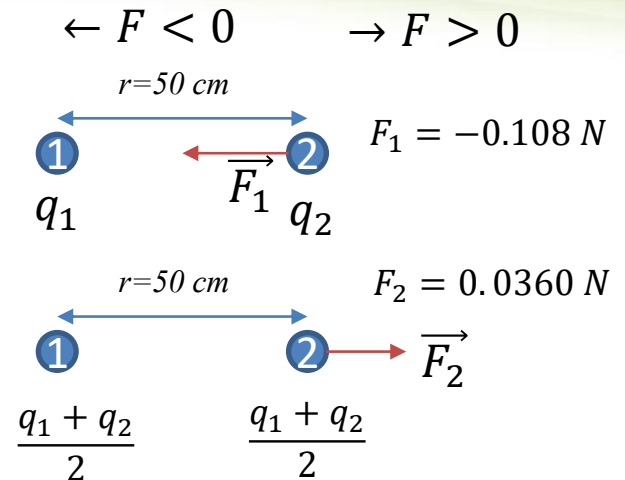


Fig. 21-21 Problem 2.

- Initial force: Repulsive $F = k q^2 / r^2$
- Final force: Repulsive $F' = k \frac{(q/2)(3q/4)}{r^2} = \frac{3}{8} k \frac{q^2}{r^2}$
- $\frac{F'}{F} = \frac{3}{8} = 0.375.$

Q**9

Two identical conducting spheres, fixed in place, attract each other with an electrostatic force of 0.108N when their center to center separation is 50cm. The spheres are then connected by a thin conducting wire. When the wire is removed, the spheres repel each other with an electrostatic force of 0.036N. Of the initial charges on the spheres, with a positive net charge, what was (a) the negative charge on one of them and (b) the positive charge on the other?



- $F_1 = \frac{1}{4\pi\epsilon_0} \frac{q_2 q_1}{r^2} = k \frac{q_2 q_1}{r^2} = -0.108 \text{ N} \rightarrow q_2 q_1 = \frac{0.108 r^2}{k} = -3.00 \times 10^{-12} \text{ C}^2$
- $q_2 = -\frac{3.00 \times 10^{-12}}{q_1} \text{ C}$
- $F_2 = \frac{1}{4\pi\epsilon_0} \frac{\frac{q_1 + q_2}{2} \frac{q_1 + q_2}{2}}{r^2} = k \frac{(q_1 + q_2)^2}{4r^2} = 0.0360 \text{ N} \rightarrow q_1 + q_2 = r \sqrt{\frac{(4)(0.0360)}{k}} = 2.00 \times 10^{-6} \text{ C}$
- $q_1 - \frac{3.00 \times 10^{-12}}{q_1} - 2.00 \times 10^{-6} = 0 \rightarrow q_1^2 - 2.00 \times 10^{-6} q_1 - 3.00 \times 10^{-12} = 0$
- $q_1 = -1.00 \times 10^{-6} \text{ C}; \quad q_2 = 3.00 \times 10^{-6} \text{ C}$
- $q_1 = 1.00 \times 10^{-6} \text{ C}; \quad q_2 = -3.00 \times 10^{-6} \text{ C}$

Q**16

In Fig. 21-26a, particle 1 (of charge q_1) and particle 2 (of charge q_2) are fixed in place on an x axis, 8cm apart. Particle 3 (of charge $q_3 = +8.0 \times 10^{-19} \text{ C}$) is to be placed on the line between particles 1 and 2 so that they produce a net electrostatic force $\vec{F}_{3,net}$ on it. Figure 21-26b gives the x component of that force versus the coordinate x at which particle 3 is placed. The scale of the x axis is set by $x_s = 8.0 \text{ cm}$. What are (a) the sign of charge q_1 and (b) the ratio q_2/q_1 ?

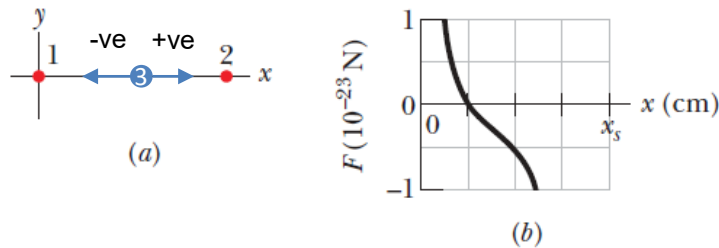
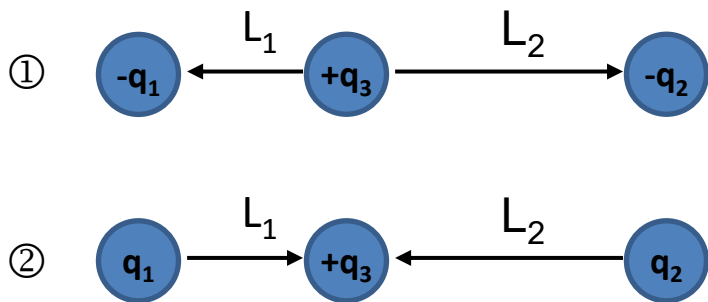


Fig. 21-26 Problem 16.



X
 $q_2 > q_1$

$q_2 > q_1$

- (b) We note that it crosses zero at $r = 0.020 \text{ m}$ (which is a distance $d = 0.060 \text{ m}$ from q_2). Using Coulomb's law at that point, we have

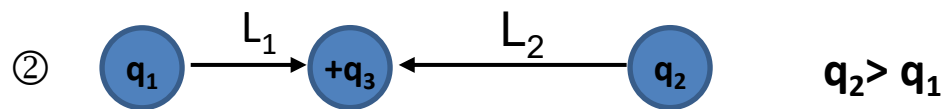
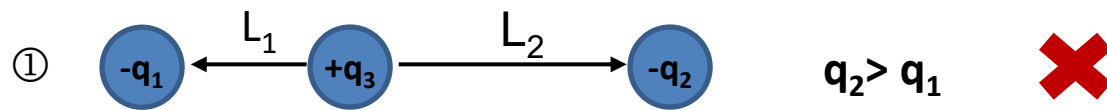
$$\frac{1}{4\pi\epsilon_0} \frac{q_1 q_3}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{q_3 q_2}{d^2}$$

$$q_2 = \left(\frac{d}{r}\right)^2 q_1$$

$$q_2 = \left(\frac{0.060 \text{ m}}{0.020 \text{ m}}\right)^2 q_1$$

$$q_2 = 9.0 q_1,$$

$$q_2/q_1 = 9.0$$



Q*25

How many electrons would have to be removed from a coin to leave it with a charge of $+1.0 \times 10^{-7} \text{ C}$?

$$n = \frac{|q|}{e} = \frac{1.0 \times 10^{-7} \text{ C}}{1.6 \times 10^{-19} \text{ C}} = 6.3 \times 10^{11}$$